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(56) Documents Cited
GB 2271124 A **GB 2271044 A** **WO 95/26121 A**
US 5084125 A

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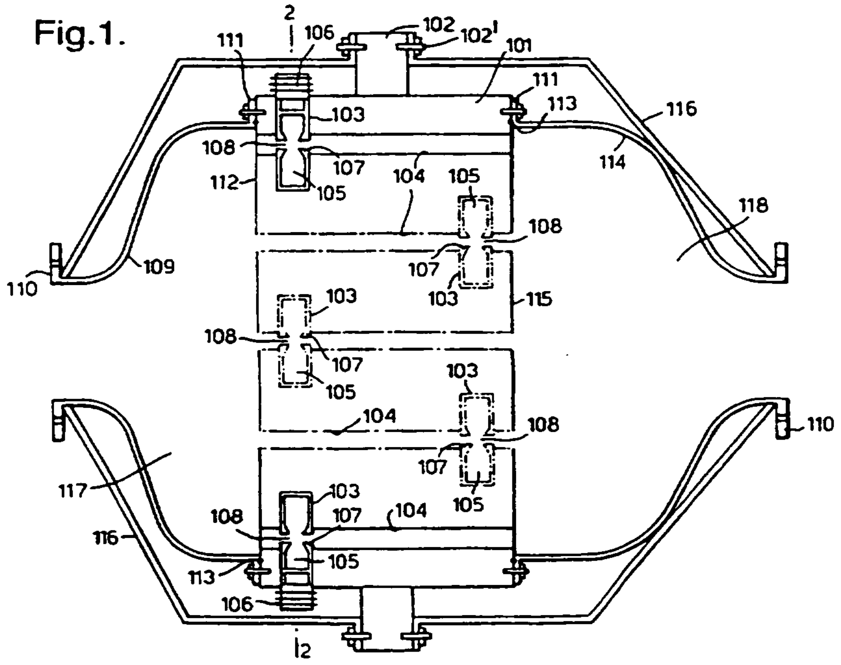
INT CL^6 **H01J 37/32 , H05H 1/24 1/46**

(54) Abstract Title
Plasma processing

(57) A plasma processing apparatus comprises a plurality of plasma reaction chambers 105, an inlet to feed a gaseous medium simultaneously to each chamber, a plasma generator in each chamber and an outlet for removing the gaseous medium from the chamber. Each chamber in a housing 103 and has a magnetron 106 connected to it. Staggered sets of housings may be mounted around the inner periphery of the apparatus (Figure 2). Provision is made to monitor (Figure 5) the effluent for reaction products or unprocessed constituents which may be recirculated by a pump (302 Figure 3). A cooled reaction chamber is disclosed (Figure 4).

Fig.1.



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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

Fig.1.

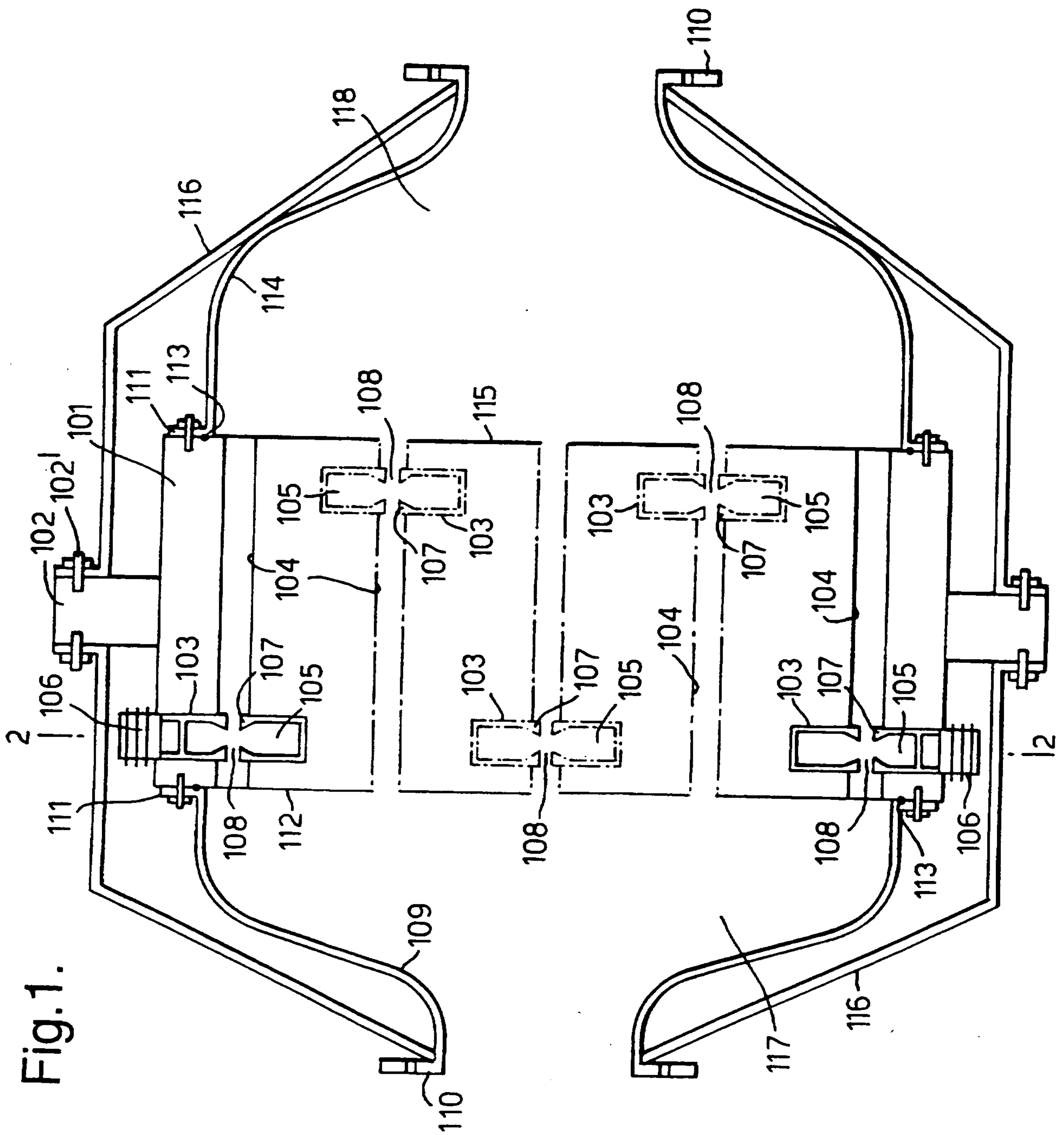


Fig.2.

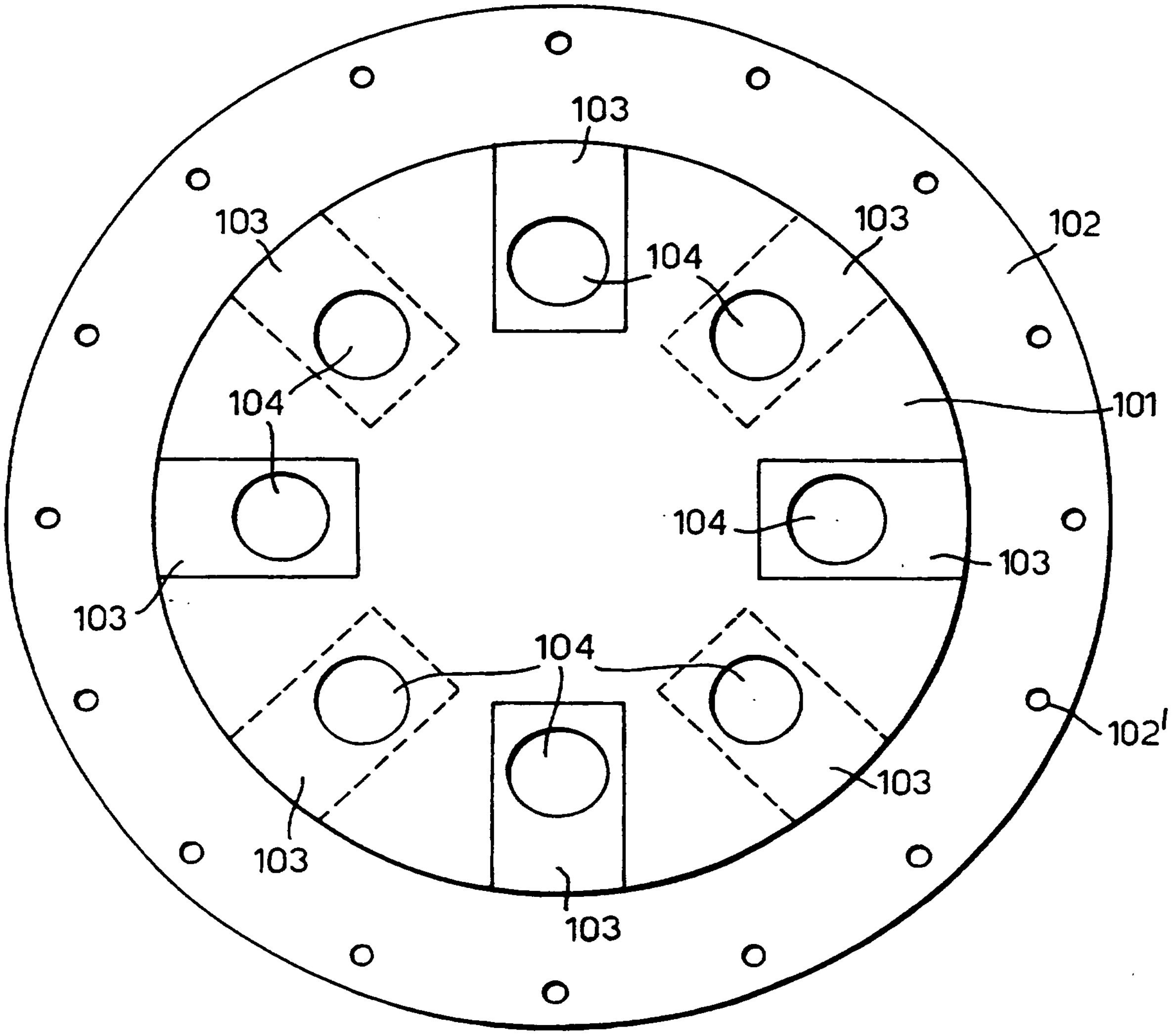


Fig.3.

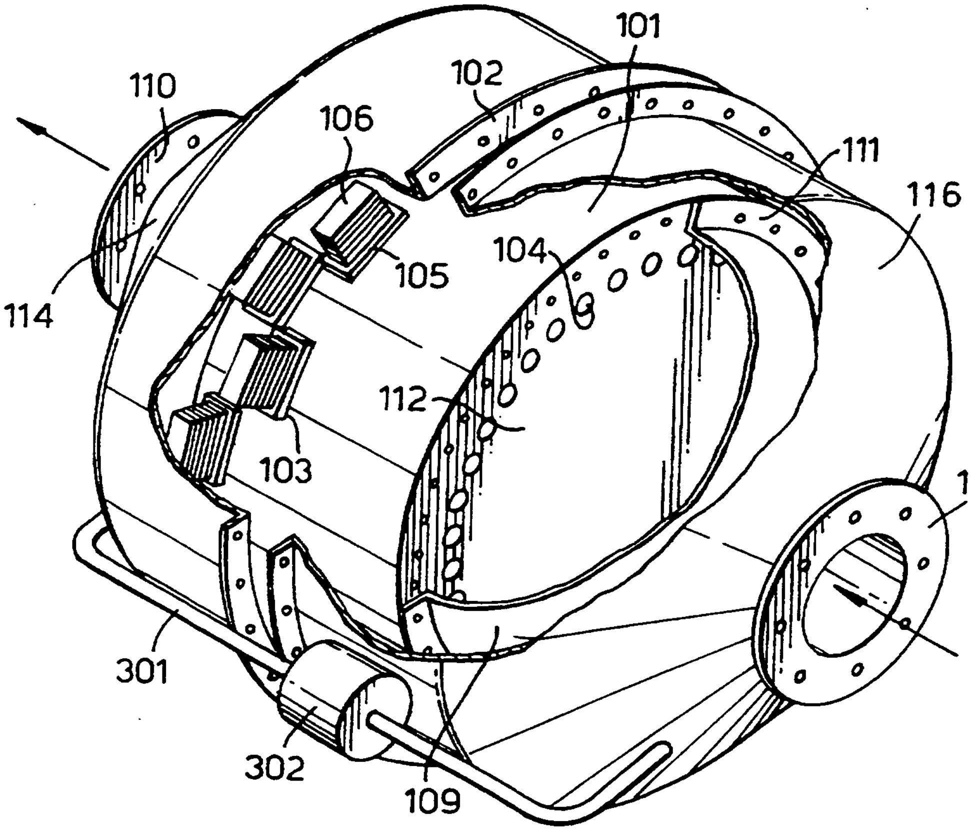
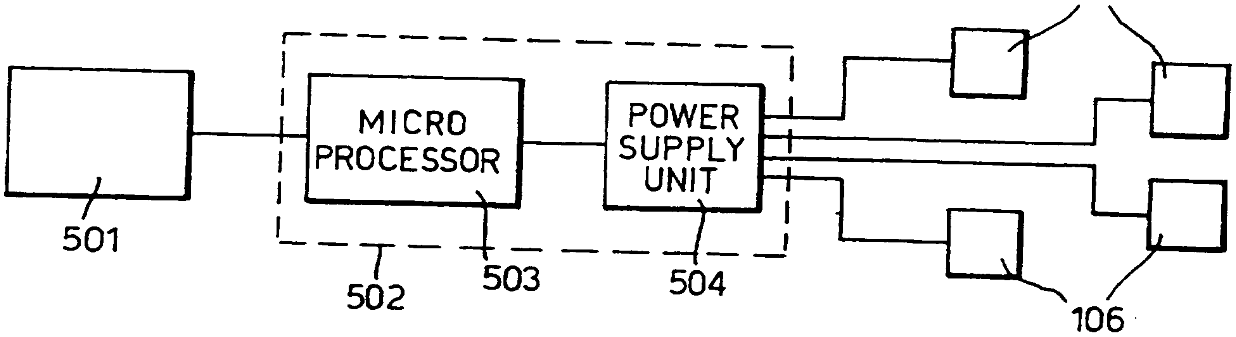
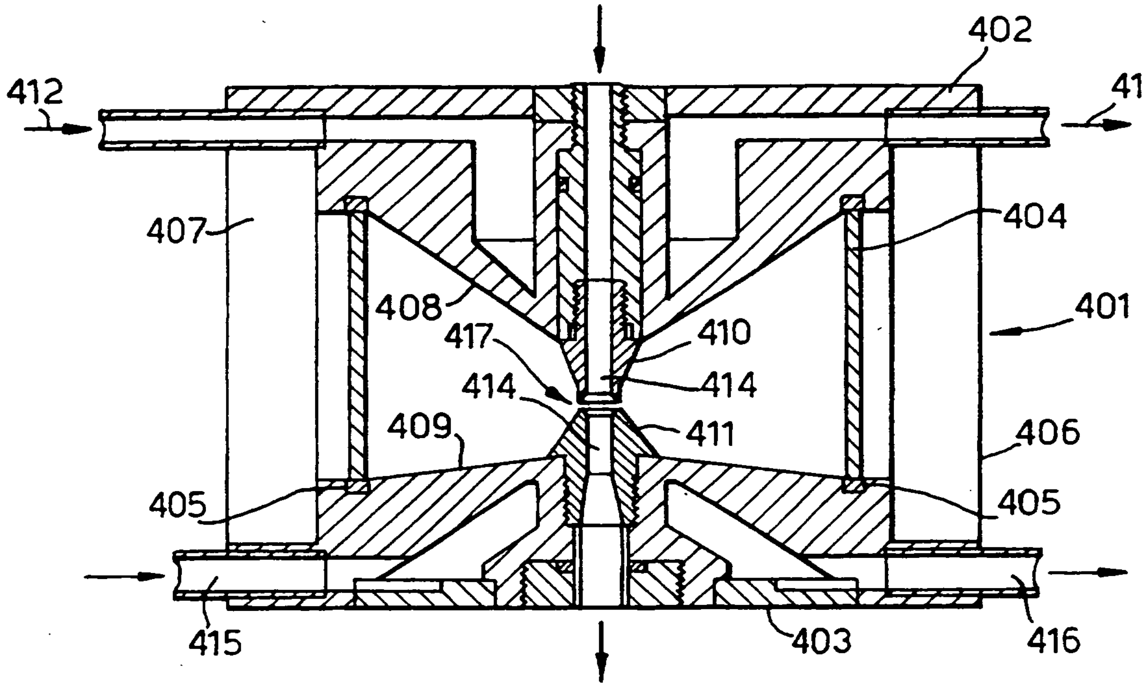


Fig.5.



MICRO PROCESSOR
POWER SUPPLY UNIT

Fig.4.



Plasma Processing

The present invention relates to the processing of gaseous media by means of plasmas.

One of the factors which is inhibiting the acceptance of the technique of processing gaseous media by means of plasmas is that the creation, maintenance and containment of relatively large volumes of plasma is energy intensive and difficult. Thus, while a number of plasma processing systems have been proposed, see for example those disclosed in our co-pending application GB 2 282 738A and patent GB 2 262 421 B, in practice their use has been inhibited by the fact that their throughput is limited.

It is an object of the present invention to provide a plasma processing system which is scaleable, energy efficient and flexible in response to changes in process conditions.

According to the present invention there is provided a modular plasma processing apparatus comprising a plurality of plasma reaction chambers, inlet means arranged to feed simultaneously a gaseous medium to be processed to each plasma reaction chamber, means for generating separately a plasma in each plasma reaction chamber, and outlet means for removing the processed gaseous medium from the plasma reaction chamber.

Preferably the inlet means and the means for removing the processed gaseous medium from the plasma reaction chambers comprise plenum chambers with which the plasma reaction chambers communicate and which terminate in standard industrial coupling flanges.

Preferably, the means for generating separately the plasma in the plasma reaction chambers comprises a microwave generator coupled directly to an associated plasma reaction chamber and there is included means for controlling each microwave generator separately. A preferred form of microwave generator is a magnetron operating at a frequency of 2.45 Ghz.

Preferably there is included means for monitoring the concentration in the gaseous medium of one or more constituents to be processed and means for varying the amount of energy supplied to each plasma generator, and hence the amount of plasma generated in each plasma reaction chamber, accordingly. Alternatively, the proportion of the active plasma reaction chambers can be varied.

Alternatively, the effluent from the plasma reaction chamber can be analysed either to determine the concentration of reaction products or the presence of unprocessed constituents of the original gaseous medium, and the action of the plasma reaction chambers varied as before. If the invention is to be used for purification processes, the latter technique may be preferred.

There may be provided also means for recirculating a proportion of the effluent from the apparatus to the inlet, and means for adding a reagent gas to the gaseous medium, either generally via the inlet to the apparatus or individually to each of the plasma reaction chambers.

The invention will now be described, by way of example, with reference to the accompanying drawings, in which, Figure 1 is a schematic longitudinal section of an embodiment of the invention,

Figure 2 is a schematic cross-section view of a mounting incorporated in the embodiment of Figure 1,

Figure 3 is a schematic longitudinal section of a modified version of the embodiment of Figure 1,

Figure 4 is a schematic longitudinal section of one of the plasma reaction chambers incorporated in the embodiment of Figures 1 to 3, and

Figure 5 is a schematic diagram of a system for controlling the action of the embodiments of the invention shown in Figures 1, 2 and 3.

Referring to Figure 1, a modular plasma processing apparatus 100 consists of a cylindrical mounting 101 made of stainless steel which has a central flange 102 in which there is a ring of studs 102'. In the mounting 101 are two radial arrays of housings 103 and axial passages 104 which extend through the mounting 101. Inserted into each housing 103 is a plasma reaction chamber 105 each of which has a magnetron 106 coupled directly to it. The magnetrons 106 are individually connected to a power supply unit, which is not shown in the drawing.

The two arrays of housings 103 are staggered as shown in Figure 2. Inside each plasma reaction chamber 105 there is a pair of conical field-enhancing electrodes 107 each of which has an axial hole 108 in it. Thus there is a continuous passage for a gaseous medium to be processed from one side of the apparatus to the other. A first section 109 of flared ducting has a standard industrial coupling flange 110 at one end and a flange

111 at the other, by means of which it is fastened to one plane surface 112 of the housing 101, the joint being sealed by an O-ring seal 113. A similar section 114 of flared ducting is attached to the other plane surface 115 of the housing 101. Components which correspond with similar components of the section of ducting 109 have the same reference numerals. An outer safety shroud 116 is attached to the flange 102 on the housing 102. As shown in the figure, the section of ducting 109 forms an inlet plenum 117 and the section of ducting 114 forms an outlet plenum 118.

The electrodes 107 which are situated in the plasma reaction chambers 105 are provided with passages through which a cooling medium can be circulated. For convenience, neither these nor the associated pipework are shown. Also, in the apparatus described a total of eight plasma reaction chambers 105 are shown. However, if desired, many more can be included as shown in Figure 3, which is a schematic isometric representation of a modified apparatus in which some of the effluent from the plasma reaction chambers 105 is recirculated and injected into the plenum chamber 117 formed by the ducting 109 via a duct 301 and a pump 302.

A simplified longitudinal section of one of the reaction chambers 105 is shown in Figure 4. Each of the plasma reaction chambers 105 consists of a chamber 401 comprised of two stainless steel end-plates 402 and 403, a cylindrical wall 404 made of quartz which is mounted in the end-plates 402 and 403 and rendered gas tight by means of O-ring seals 405. An outer wall 406 forms part of a waveguide 407 by means of which energy is supplied to the chamber 401. The assembly is clamped together by set screws, which are not shown in the drawing. Also included, but not shown in the drawing is means for coupling microwave radiation into the interior of the chamber 401. Each of the end-plates 402 and 403 has a conical protuberance 408 and 409, respectively, which terminate in sharp annular tips 410 and 411 respectively. The tips 410 and 411 are screwed into their respective end plates 402 and 403 so that they can be replaced as and when necessary. A suitable material for the tips 410 and 411 is tungsten, hastalloy, or a similar refractory metal.

The end plate 402 has an inlet 412 and an outlet 413 for a coolant medium. The end plates 402 and 403 and the tips 410 and 411 have an axial hole 414 by means of which the said gaseous medium is extracted from the chambers 401. Again, the end plate 403 is hollow and there is an inlet 415 and an outlet 416 for a cooling medium. The gap 417 between the tips 411 and 412 of the protuberances 409 and 410 on the end plates 402 and 403 is adjustable between 0.1 and about 5 mm. The assembly provides the pair of electrodes 107 shown in Figure 1.

In use, the gaseous medium to be processed is passed through the chamber 401 via the axial holes 104 in the mounting 101 at a pressure in the range .001 to 2 bar, and microwave radiation at a frequency of 2.45 Ghz and power of up to 2 kilowatts is coupled into the chamber 101 in such a manner that the electrodes 107 provided by the protuberances 109 and 110 of the end-plates 402 and 403, respectively of the chamber 401 are transverse of the direction of propagation of the microwaves through the chamber 401. The electrodes 107 concentrate the microwave radiation in the chamber 401 to such an extent that the gaseous medium is excited to the plasma state in the region of the gap 417 between them.

The upper tip 410 of the pair of electrodes 107 may have a plurality of regularly spaced radial holes drilled in it so that in use, a proportion of the gaseous medium passes out of them and is drawn into the gap 417 between the electrodes 107 by means of the venturi effect caused by the flow of the gaseous medium from the upper to the lower of the electrodes 107, so helping to confine the plasma formed in the gaseous medium to the region of the gap 417 between the electrodes 107.

Referring to Figure 5, one of the plasma reaction chambers 105, as shown in our co-pending application GB 96/10841.4, is adapted to act as a sensor 501 for a control system 502 which is arranged to control the action of the remaining plasma reaction chambers 105. Optical data gathered from the sensor 501 is analysed in a microprocessor 503 to determine the presence and partial pressure of specified components of the gaseous medium passing into the plasma processing apparatus.

The microprocessor 503 also is arranged to generate control signals which are applied to the power supply unit 504 which is connected to the magnetrons 106 of each plasma reaction chamber 105 (four of which are shown in the figure). The power supply unit 504 can be arranged either to vary the power supplied to all the magnetrons 106 as a function of the partial pressure of the specified components of the gaseous medium, or to vary the number of magnetrons 106 which are operational, again as a function of the partial pressure of the specified components of the gaseous medium. In the case where an inlet plenum chamber is used, the first system is preferred. In the case where separate inlet pipes to each plasma chamber 105 are used, the second system can be adopted. In this case, electrically operated inlet valves can be used so that the number of plasma reaction chambers 105 in circuit can be matched to the amount of gaseous medium to be processed.

Alternatively, and particularly if the apparatus is to be used for the removal of a noxious component from a gaseous medium, a gas analyser can be positioned downstream of the plasma reactor chambers 105.

There may be included means for supplying a reagent gas adapted to enhance the action of the plasma, either to the inlet plenum chamber into each of the plasma reaction chambers 105 separately.

The reagent gas may be such as to enhance the formation of active species in the gaseous medium, or to facilitate oxidation or reduction reactions in the gaseous medium, as is known in the plasma processing art.

The invention is not restricted to the details of the foregoing examples. For instance the components made from stainless steel may be made from other suitable material which is corrosion resistant under the conditions of operation. In particular, stainless steel is attacked by certain gases and is therefore unsuitable where these are to be treated.

Claims

1. A modular plasma processing apparatus comprising a plurality of plasma reaction chambers, inlet means arranged to feed simultaneously a gaseous medium to be processed to each plasma reaction chamber, means for generating separately a plasma in each plasma reaction chamber, and outlet means for removing the processed gaseous medium from the plasma reaction chamber.

2. An apparatus according to Claim 1 wherein the inlet and outlet means comprise plenum chambers with which the plasma reaction chambers communicate.

3. An apparatus according to Claim 1 or Claim 2 wherein the means for generating separately the plasma in the plasma reaction chambers comprises a microwave generator coupled directly to an associated plasma reaction chamber.

4. An apparatus according to Claim 3 wherein there is included means for controlling the action of the microwave generators.

5. An apparatus according to Claim 4 wherein the means for controlling the action of the microwave generators comprises means for determining the partial pressure of a component of the gaseous medium and means for varying the power supplied to the microwave generators as a function of the partial pressure of the component of the gaseous medium.

6. An apparatus according to Claim 5 wherein the means for varying the power supplied to the microwave generators is adapted to vary equally the power supplied to each of the microwave power generators.

7. Apparatus according to Claim 6 wherein the means for varying the power supplied to the microwave generators is adapted to vary the number of microwave generators to which power is supplied.

8. Apparatus according to Claim 5, 6 or 7 wherein one of the plasma reaction chambers is adapted to act as a sensor for the measurement of the partial pressure of the said component of the gaseous medium.

9. Apparatus according to any of Claims 1 to 3 wherein there is included means for monitoring the constitution of the effluent from the plasma reaction chambers and means for varying the action of the plasma reaction chambers to maintain the partial pressure of a component of the effluent within predetermined limits.

10. Apparatus according to Claim 9 wherein the means for varying the action of the plasma reaction chambers comprises means for varying the power supplied to the microwave generators.

11. Apparatus according to Claim 10 wherein the means for varying the power supplied to the microwave generators is adapted to vary equally the power supplied to the microwave generators.

12. Apparatus according to Claim 10 wherein the means for varying the power supplied to the microwave generators is adapted to vary the number of microwave generators to which power is supplied.

13. Apparatus according to any preceding claim including means for extracting a proportion of the effluent from

the plasma reaction chambers and adding it to the gaseous medium supplied to the plasma reaction chambers.

14. Apparatus according to any preceding claim wherein there is included means for adding a reagent gaseous medium to the said gaseous medium.

15. Apparatus according to Claim 14 wherein the reagent gaseous medium is added to the said gaseous medium prior to its admission to the plasma reaction chambers.

16. A modular plasma processing apparatus substantially as hereinbefore described and with reference to the accompanying drawings.

Application No: GB 9707205.2
Claims searched: 1 to 16

Examiner: J L Freeman
Date of search: 19 June 1997

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:
UK Cl (Ed.O): H1D (DGP, DGQ); H5H
Int Cl (Ed.6): H01J (37/32); H05H (1/24, 1/46)
Other:

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB 2271124 A	(OPA Amsterdam)	1
X	GB 2271044 A	(OPA Amsterdam)	1
X	WO 95/26121 A	(Abtox Inc) Figure 3	1
X	US 5084125	(N Aoi) Figure 3	1

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.